

### METEOROLOGY IN THE PHYSICAL LABORATORY.

It is well known that for many years the Editor has endeavored to stimulate the study of dynamic meteorology as a combination of laboratory methods with analytical mechanics. A man familiar with hydrodynamics and thermodynamics should be able to make their application to the atmosphere a most interesting subject, and eventually build up a school of mathematical physics applied to meteorology that will be as important to the university as it will be to the advancement of the science.

The following article, by Brunhes, illustrates the class of work to be done in such a laboratory; and many similar examples of careful experimentation could be adduced. At the Peoria convention the Editor sketched out the plan of a work entitled "A handbook of laboratory work leading up to research in meteorology", in which, by a well graded series of experiments, the student proceeds, step by step, until he has explored the prominent feature of atmospheric phenomena, comparing his measurements with his theories until he has obtained a clear idea of the processes that are going on in nature.—C. A.

### ACTION OF A HORIZONTAL AIR CURRENT UPON A VERTICAL WHIRLWIND.

By BERNHARD BRUNHES.

[Translated by Chester L. Mills from the Comptes Rendus of the Academy of Sciences, Paris, April 29, 1907. Vol. CXLIV, p. 900.]

I have been conducting an experimental research as to the mechanical action exerted by a horizontal air current upon a whirlwind with a vertical axis susceptible of lateral displacement. I have recognized that the phenomenon follows the following law:

A horizontal current exerts on a movable vertical whirlwind that has a sinistrorsal rotation, a horizontal force perpendicular to the current and directed to the left; the force is directed toward the right of the current if the motion of the whirlwind is dextrorsal.

1. I have had recourse to the apparatus of Weyher for the production of a vertical whirling column of air. A vertical box 140 centimeters high and 50 centimeters on a side has three vertical wooden sides, the fourth being of glass before which the observer places himself. At the top is fixed a revolving drum which may be rotated in either direction at will by a small motor. The vertical whirling column is rendered visible by a white smoke of ammonium chlor-hydrate, produced by placing on the floor of the box an evaporating dish full of [hydrochloric] acid in the middle of a vessel of ammonia.

Against a given point of the vertical column of smoke is directed a jet of air generated by an electric fan and carried to the center of the box by a horizontal bent glass tube, which is terminated by a branch, *A*, perpendicular to the glass front of the box and ending a few centimeters from the axis. With a sinistrorsal (counterclockwise) whirling column, the observer standing before the glass front sees the column deviate to his left at the height of the tube *A*; and, continuing to inflect itself and to oscillate, it maintains itself at the right of the tube *A*, if the jet of air is strong enough.

2. A second tube, *B*, exactly in the line of the prolongation of *A*, opens opposite the orifice of *A*, conducting the air which escapes from it from the rear to the front. A stopcock allows the air from the fan to enter by either *A* or *B*, as desired. When the direction of the whirling column is sinistrorsal, the revolving column is deflected to the left if the air enters by *A*, but to the right if the air enters by *B*. With a dextrorsal rotation of the whirling column, the result is reversed, altho it is proper to remark that a column of smoke with dextrorsal rotation is produced and maintained less easily than one with sinistrorsal rotation.

The interior diameter of the tubes *A* and *B* being 8 milli-

meters, and the speed of the drum one thousand revolutions per minute, for a current of air 30 meters per second, blowing upon the vertical column 65 centimeters from the bottom, there is produced a mean displacement of 15 to 25 millimeters when we pass from tube *A* to tube *B*.

3. I endeavored to check these results by manometric measurements, with a pressure receiver (*prise de pression*) which made it possible to explore the hydrodynamic field of the whirling column and its neighborhood. This pressure receiver is the end of a small horizontal tube, *T*, bent vertically, and capable of being displaced in two directions, forward and backward, and from right to left. The glass tube is connected by a rubber tube to a water manometer with an inclined arm, giving about 1 centimeter displacement for a variation in pressure of 1 millimeter of water.

On moving the tube *T* a minimum of pressure is found to correspond to the case where the vertical arm of the small tube is in the axis of the whirling column. If a horizontal jet of air is directed from *A* or *B* on the vertical arm of the tube *T*, being careful always to blow a little below the opening, so as not to exert, by means of the jet, a direct influence on the free end, it is observed that the manometer rises a little whether one blows from the front or from the back. Again, to find the minimum of pressure it is necessary to push in or draw out the tube *T* so that its extremity will be a little to the left of its initial position (8 to 10 millimeters) if one blows from front to back thru *A*, and when the whirling column is sinistrorsal; but, on the contrary, to the right if one blows from back to front thru *B*.

When the exploring tube *T* is placed in a position such that its extremity is 8 millimeters to the left of the position of minimum pressure without the air jet, there is clearly an increase in pressure (from 0.3 to 0.5 millimeters) when the stopcock is manipulated so as to substitute the rear jet for the one in front. The reverse is the case (with the sinistrorsal whirling column in every case) if the end of the exploring tube is placed 8 to 10 millimeters to the right of the initial position of minimum pressure.

### CHARACTERISTICS OF THE INTERTROPICAL ATMOSPHERIC CIRCULATION.<sup>1</sup>

[Translated by Chester L. Mills from the Comptes Rendus of the Academy of Sciences, Paris, April 8, 1907.]

Last year we presented to the academy the results obtained during the first two cruises of the *Otaria*. Since that time the discussion of the observations on the second voyage, of 1906, has been brought to a conclusion, which enables us to state with precision some of the characteristics of the circulation of the air in the intertropical region of the Atlantic.

The north to east trade winds ordinarily extend to an altitude of only several hundred meters. In this stratum the decrease in temperature is very rapid, as one may judge from the following figures which result from ascensions of kites and sounding balloons:

*Decrease in temperature per 100 meters of ascent.*

Position.	0 to 200	200 to 400	400 to 600	600 to 800	800 to 1000	1000 to 1100	1100 to 1200	1200 to 1400	Method.
To the north of parallel 25° N.	°C. 1.3	°C. 1.0	°C. 0.6	°C. 0.35	°C. 0.4	°C. 0.1	°C. 0.8	.....	Kites.
To the south of parallel 25° N.	+1.8	+0.9	+0.3	—0.75	—0.5	0.0	—1.0	+0.7	Kites.

Six sounding balloons (mean latitude 30° N.) gave a diminution of 1.8° C. for the first 500 meters, with the minimum rate of diminution of temperature at about 1250 meters.

Six sounding balloons at the equator (mean latitude 1° N.)

<sup>1</sup> Note by Messrs. L. Teisserene de Bort and A. L. Rotch, presented by M. Mascart.

gave a diminution of  $1.2^{\circ}$  C. for the first 500 meters, with an inversion of the rate at the mean altitude of 1000 meters.

Above the stratum of rapid diminution comes a zone where the wind diminishes in force, and in which the temperature ordinarily presents inversions. Moreover, this phenomenon has already been observed by M. Hergesell for the region between the Azores, Madeira, and the parallel of  $26^{\circ}$  N., but it is general in its character, and is found again in the northern intertropical zone and in the southeast trade wind of the Southern Hemisphere, which has been studied as far as the Island of Ascension.

Apropos of this inversion, whose cause is not yet established, we call attention to the fact that Biot in his memoir "On the true constitution of the terrestrial atmosphere", published in 1841 in the *Connaissance des Temps*, when discussing the observations of Humboldt in the equatorial region of the Cordilleras, represented the variation of temperature with altitude by a parabola whose summit, located at an altitude of about 800 meters, corresponded to an inversion of temperature: this latter, moreover, was deduced only from calculations without having been observed directly. The observations made on the *Otaría* fully justify the view held by this celebrated physicist.

Above the northeast trade winds are ordinarily observed currents from different directions; the greater part of the time these come from the northwest, but may alternate with other winds. Going still higher, we find those currents with southerly components that constitute the antitrade winds; these currents begin at a low altitude in the region of the equator, where they are found on an average below 2000 meters, while at the Tropics they are met with at about 2500 meters, and again in the latitude of Teneriffe several hundred meters higher.

As we have already pointed out, the antitrade wind as a whole indicates clearly the effect of the earth's rotation; it is first from the southeast, then becomes south, and next southwest; it ends as a west wind in the latitude of the Azores.

The region of ascending air near the equator is occupied by winds in which the easterly component predominates at the various altitudes that have been explored, namely, from the level of the sea up to 14 kilometers.

In the neighborhood of Ascension we find again above the southeast trades the winds of the southern antitrades, having northerly components, with several intercalated strata moving from the southwest, corresponding to the northwest winds of our hemisphere.

To the north of the Tropic [of Cancer] the regularity of the trades and antitrades diminishes. In these parts it sometimes happens that the trade wind extends to an altitude of 6 to 8 kilometers, the antitrade having been deflected to the right or to the left, but these conditions are transitory.

North of latitude  $25^{\circ}$  N. one finds that in summer the trades and antitrades predominate from the neighborhood of the Canaries to about longitude  $37^{\circ}$  W. On going farther toward America the south and southwest winds become predominant in the lower strata, a fact that is fully explained by the distribution of isobars, which are themselves determined by the course of the isotherms.

#### THE VELOCITY OF CENTERS OF HIGH AND LOW PRESSURE IN THE UNITED STATES.

By C. F. VON HERRMANN, Section Director. Dated Baltimore, Md., May 9, 1907.

The fact that the general motions of the atmosphere have a controlling influence upon the direction of motion and velocity of cyclones was recognized by Espy as early as 1841.<sup>1</sup> Ferrel, in 1859, suggested that the upper currents carry them along as a stream of water carries along the whirling eddies which

we find in it.<sup>2</sup> We are indebted, however, to Loomis for the classical investigation of the velocity of storms in the United States.<sup>3</sup> Loomis found the average velocities from the weather maps for thirteen years, 1872 to 1884, and his results have been quoted quite generally in books on meteorology.<sup>4</sup>

The publication of Mr. Edward H. Bowie's new method of ascertaining the direction and velocity of single depressions gives new importance to the accurate determination of the mean rate of speed of storms as observed under different conditions in the past, and suggested the idea of recalculating the average velocities of highs and lows in the United States from the material supplied by the MONTHLY WEATHER REVIEWS. From 1878 to March, 1904, the latitude of origin and of disappearance, the length of path and velocities of high and low pressure areas have been published regularly, and the task of assembling the data for the entire period of twenty-six years was not a difficult one.

The results are given in Table 1, mean velocities and number of areas of low pressure in the United States, 1878-1904 (miles per hour). A comparison with the averages obtained by Loomis for the period 1872 to 1884 shows substantial agreement.

*Velocity of storms, Loomis, 1872-1884.*

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
33.8	34.2	31.5	27.5	25.5	24.4	24.6	22.6	24.7	27.6	29.9	33.4	28.4

*Weather Bureau records, 1878-1904.*

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
34.8	34.8	31.6	26.9	24.3	24.0	24.4	24.6	24.8	27.4	30.7	34.9	28.6

The average annual velocity from the Weather Bureau records is slightly higher than the earlier averages found. The only marked discrepancy occurs in August; the longer period does not show so marked a minimum velocity in that month as we find in Loomis's records. The minimum occurs in June. On the whole the mean velocities are very nearly equal during the 3 winter months, averaging about 35 miles an hour. There follows a brief transitional period when the velocity diminishes (March and April). During the 5 months from May to September, inclusive, the velocity does not vary widely from the mean of 24.4 miles. Again during October and November there is a transitional period with increasing velocities.

The general eastward motion of the atmosphere increases gradually upward from the earth's surface. Ferrel calculated that the eastward movement in the upper atmosphere is about 26 miles an hour at an elevation of 2.5 miles,<sup>5</sup> but Professor Bigelow in his *International Cloud Report* states that the maximum development of cyclones takes place at an elevation of from 3 to 4 miles, where the progressive motion of the air must be considerably greater, in fact agreeing closely with the speed of whirlwinds at the surface. The difference between the summer and winter velocities is quite marked; the ratio of the means during the two seasons is in round numbers 24 to 35, or nearly 1 to 1.5.

<sup>2</sup> Motion of Fluids and Solids relative to the Earth's Surface, 1859, as mentioned in Ferrel's *Treatise on Winds*, page 275.

<sup>3</sup> Contributions to Meteorology, Elias Loomis, 1886.

<sup>4</sup> The policy adopted by Gen. A. J. Myer was to confine the meteorological work of the Signal Service to observations and forecasts and the collection of data for the use of those professional meteorologists outside the Government service who were endeavoring to improve the science, properly so called. Therefore the Signal Service published little or nothing relating to theoretical meteorology during his administration, altho numerous studies were in progress as unofficial work. With regard to the movement of areas of high and low pressure reference may be made to the tables for 1872 and 1873, given at pages 154-159 of Part II of the Annual Report of the Chief Signal Officer, 1889, and especially to the tables by Professor Garriott contained in Bulletin A, "Summary of International Meteorological Observations", Washington, 1893.—C. A.

<sup>5</sup> Ferrel's *Treatise on Winds*, page 277.

<sup>1</sup> Espy: *Philosophy of Storms*, 1841.